A Survey on Swarm Intelligence based Routing Protocols in Wireless Sensor Networks

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Abstract: Recently, wireless sensor networks have attracted many researchers. One of the main topics adopted by researchers studying on wireless sensor networks is developing routing protocols for wireless systems. Routing protocol development concerns to deal with problems such as complexity, scalability, adaptability, survivability and battery life in wireless systems. Routing protocols grounded for wireless systems are developed in order to solve these problems. In this paper, we briefly discussed especially swarm intelligence based routing protocols for wireless sensor networks.

1. Introduction

Wireless sensor networks (WSN) are such networks in which numerous small scale sensors are nodes communicating via wireless channels. Current developments in wireless communications and digital electronics render possible to design sensor units with low power consumption, small size and short range communication capability. WSN architectures including many processing sensors having such properties provide significant advantageous on classic sensor systems.

Large-scale sensor networks can be deployed to around of the measured region in some applications. Each sensor unit is randomly distributed to the region; therefore it is impossible to determine exact location of the sensors. In such applications, self organization and adaptive collaboration among sensors become key properties to provide survivable structure in the network level [1]. Collaboration and self organization among sensor units allow network to route physical information from observed environment to the base station via multihop routes. The features such as low cost of the WSN nodes deploy ability into inaccessible regions and long life without any maintenance enable sensor networks to be used a wide range of application areas. A typical sensor network is composed of observation region, sensor nodes, base station and task allocator nodes.

WSN's application areas can be exemplified as military, environmental and medical applications. Primary goals of the routing task of the WSN systems are to extend network life and to prevent connection errors emerged from use of intensive energy management techniques [2]. Therefore, there is no way to use classical routing approaches in WSNs and need for new routing approaches.

Social insect colonies such as ants and honeybees have complex collective behavior and decentralized management structure. These properties have resemblances with parallel, dynamic and distributed systems such as computer networks. Several researchers studied these insects to devise high performance routing protocols. This paper are lend itself to give brief information about swarm intelligence based routing protocols.

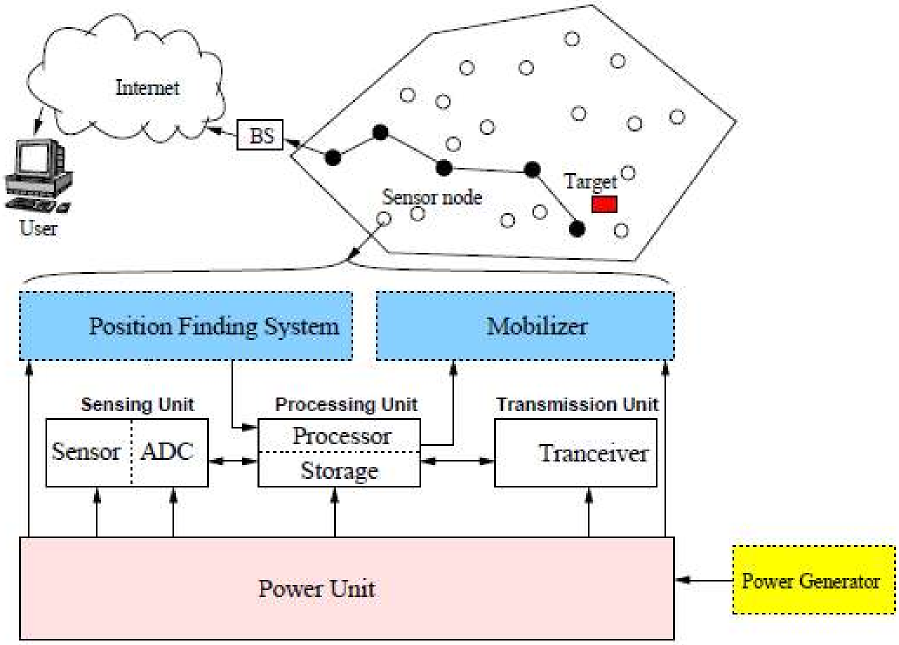

Figure 1. The components of a sensor node [1]

Following introductions, paper gives brief information about swarm intelligence in Section 2. Section 3 covers swarm intelligence based routing protocols inspired from social insects. The paper concludes with Section 4.

2. Nature-Inspired Routing Protocols

In this section, routing protocols developed by inspiring from nature systems are summarized. Main concerns in such routing protocols are Optimality, Simplicity, Robustness, Convergence, Flexibility, Scalability, Multi-path Routing, Reachability, and Quality of Service [3].

2.1. Ant Colony Optimization (ACO) Routing Algorithms

The Ant Colony Optimization (ACO) methods has been inspired by operating principles of ants [7], which empower a colony of ants to perform complex tasks like nest building and foraging [8].

2.1.1. Ant-Based Control (ABC)

Schoonderwoerd et al. [8] were the first to apply the ACO approach to routing and load balancing problems in circuit-switched telecommunication networks. As a symmetric network, a circuit-switched network reserves a virtual circuit between a sender and a receiver by explicitly connecting them through crossbar switches. Consequently, the major challenge is to distribute the calls over multiple switches so that the system can support a maximum number of possible calls during peak hours. Such a network is not able to admit calls if all input ports of a crossbar switch are connected to its output ports. Consequently, congestion could be defined as a function of the number of used connections in a crossbar switch [9]. The performance of a switching algorithm is measured in terms of the number of calls which are blocked or failed due to congestion [10].

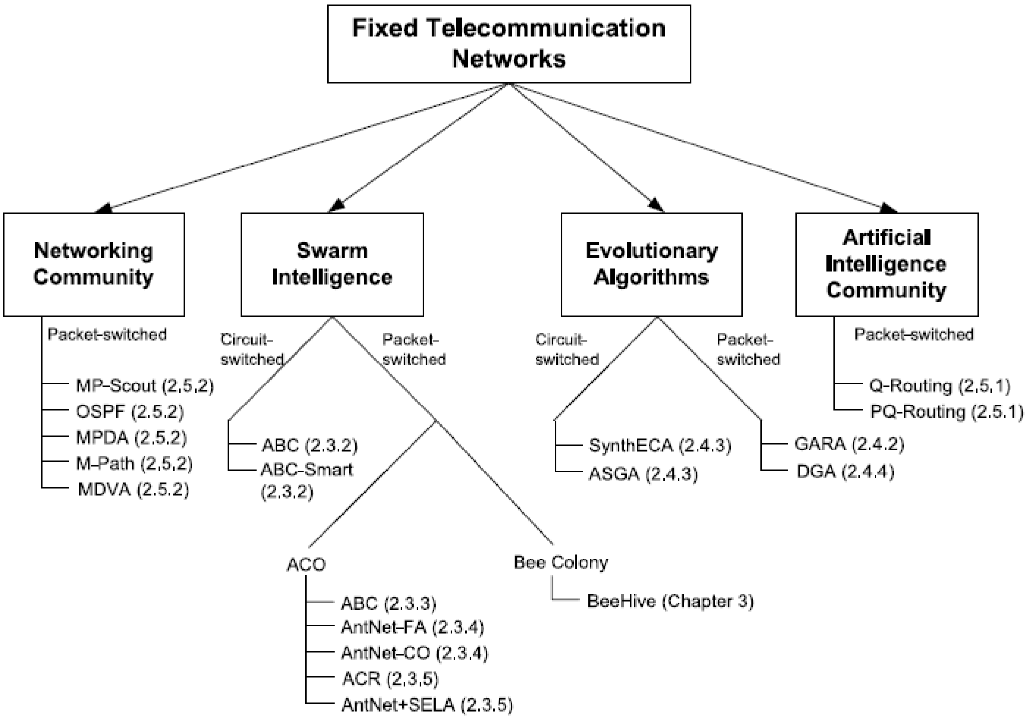

Figure 2. A taxonomy of routing protocols for fixed telecommunication Networks[3]

2.3.2. AntNet

AntNet was proposed by Di Caro and Dorigo in [11]. It is inspired by the principles of the ACO approach but has additional network-specific enhancements as well. The algorithm is designed for asymmetric packet-switched networks, and the primary objective of the algorithm is to maximize the performance of a complete network. The algorithm implicitly achieves load balancing by probabilistically distributing packets on multiple paths.

2.3.3. Ant Colony Routing (ACR) and AntNet + SELA QoS-Aware Routing

Di Caro has discussed ACR, which is a general framework for designing fully distributed and adaptive systems for network control and management, in [12]. ACR can be viewed as a distributed society of static agents, which are known as node managers, and mobile agents, which are proactively or reactively launched in the network. Node managers autonomously manage node activities by learning and then following stochastic management policies based on local pheromone values, which represent goodness of different control actions. However, they expand their "sensory field" to acquire information about their environment with an adaptive generation of mobile agents. Mobile agents take an active preceptor role on behalf of the node managers that launch them. These agents collect the important parameters that act as input parameters to learning strategies of node managers. A node manager, based on the feedback provided by preceptor agents, might alter its control actions.

2.3.4. BeeHive

BeeHive inspired by the foraging principles of honeybees. The communicative model of bees was instrumental in designing intelligent bee agents, which are suited for large and complex topologies. The results obtained from extensive simulation experiments conclude that bee agents occupy smaller bandwidth and require significantly less processor time compared to the agents of existing state-of-the-art algorithms [3].

3. Swarm Intelligence Based Routing Protocols For Wireless Sensor Networks

In this section, a brief literature is given for swarm based routing protocols for WSNs [14].

3.1. BeeSensor

Saleem and Farooq (2007) are implemented BeeHive routing protocol for wireless sensor networks which is developed originally for wired networks. BeeHive is developed by inspiration of scout-recruit system of honeybees [4].

Characteristics	Routing protocols			
	FP-Ant	EEABR	BeeSensor	AODV
Single-path (SP) vs. Multi-path (M)	M	M	M	SP
Loop free	No	No	Yes	Yes
Reactive (R) vs. Proactive (P) vs. Hybrid (H)	H	P	R	R
Static (S) vs. Dynamic (D)	D	D	D	D
Best effort (B) vs. QoS (Q)	B	B	B	B
Load balancing	Yes	Yes	Yes	No
Fault-Tolerant	Yes	Yes	Yes	Yes
Power-aware	No	Yes	Yes	No
Nexthop (N) vs. Source routing (SR)	N	N	SR	N

Table 1. Classification of routing protocols for WSNs[3]

3.2. Energy-efficient ant-based routing (EEABR)

EEABR is developed by T. Camilo in 2006 and a new communication protocol for WSNs called energy efficient ant-based routing algorithm (EEABR), which is based on the Ant Colony Optimization (ACO) [5].

EEABR uses a colony of artificial ants that travel through the WSN looking for paths between the sensor nodes and a destination node, that are at the same time short in length and energy-efficient, contributing in that way to maximize the lifetime of the WSN. Each ant chooses the next network node to go to with a probability that is a function of the node energy and of the amount of pheromone trail present on the connections between the nodes. When an ant reaches the destination node, it travels backwards trough the path constructed and updates the pheromone trail by an amount that is based on the energy quality and the number of nodes of the path. After some iteration the EEABR protocol is able to build a routing tree with optimized energy branches [5].

3.3. Flooded piggybacked ant routing (FP-Ant)

FP-Ant is developed by Ying Zhang in 2004. The flooding mechanism is significantly helpful in wireless networks, especially in sensor networks, where the probability of a packet loss is substantially higher compared to that of fixed networks. FP-Ant is a variation of the AntNet proposed in and is based on the flooding mechanism [6].
In Table 1, comparison and main features of the previous routing algorithms are listed.

4. Conclusions

Together with emergence of WSN networks, new routing approaches are required since networks have highly dynamism and distributed. When literature is investigated, it is obviously seen that routing protocols for WSNs are implementations from wired networks. The researches done have shown that swarm intelligence based routing protocols can remove at least one or several problems in the area such as battery life, scalability, maintainability, survivability, adaptability and so on. Ant based approaches are attracted by much researchers than other approaches.

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